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14. ABSTRACT
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Second search same as the first: The benefit of consistency in multiple target search

Adam T. Biggs & Stephen R. Mitroff

Abstract

Real world visual search is a complicated process subject to a variety of unavoidable pressures (e.g., time limits). As such, increasing accuracy in critical searches (e.g., baggage screening) cannot always be done by improving the situation, and so improvement must come from the searcher. Here we demonstrate that consistency in time of search completion can predict accuracy in multiple-target search for professional (TSA Officers) and non-professional searchers. Participants were more likely to miss a second target after finding a first, but increased consistency reduced this likelihood and increased overall accuracy. Nicely, consistency offers a trainable mechanism to improve performance.

Summary

Visual search experiments in the lab often require participants to find a single, well-defined target among distractors. However, real world search tasks are not always so clear-cut. For example, radiologists do not know what kind or how many abnormalities might be present, and airport baggage screeners do not know if a given bag contains water bottles, explosives, and/or other prohibited items. A key complexity to such searches is that they can contain more than one target during any given search, and such "multiple target searches" introduce unique problems. In particular, decades of research has demonstrated that when multiple targets are present, locating one can interfere with accuracy for locating additional targets; a phenomenon known as "satisfaction of search" (SOS; Tuddenham, 1962).

SOS errors are pervasive and thought to account for one third of all misses in radiology (Berbaum et al., 2010). New evidence suggests that SOS errors occur, in part, because observers allocate working memory resources to maintaining the location and identity of the first target found in a search, and that this effort alters search behaviors by effectively turning found targets into distractors (Cain & Mitroff, under review). SOS errors are also subject to a wide variety of situational factors, with second target performance affected by time pressure, anxiety, and motivation (Clark et al., 2011; Fleck et al., 2010).

Although multiple-target search presents a variety of problems, what remains unclear is how they can be overcome since individuals cannot always dictate the time pressures, motivation, or situational aspects of a given search. For example, if baggage screeners spent an hour searching each bag, no one would ever make a flight on time. If you cannot improve the search situation to enhance accuracy, then an excellent alternative is to improve the searcher.

Here we explore one possible means of enhancing multiple-target search performance—search consistency. Search consistency, or how similarly an observer performs search from trial to trial, is operationally defined here as the variability in how long an observer takes to complete a thorough search of the display. For example, a consistent searcher would take five seconds on each trial, and an inconsistent searcher might take five seconds one trial, then two seconds, then nine, and so forth (Figure 1A). We hypothesize that an observer searching the display the same way each time will be more accurate. In particular, consistent visual search may alleviate the working memory burden created by found targets (Cain et al., 2011) as consistent visual search should limit the likelihood of re-encountering found targets during subsequent search.

We have previously demonstrated that search consistency predicts accuracy in a single-target search task, and that it is particularly predictive for professional visual searchers (Mitroff et al., 2012). Our present goal is to determine whether consistency can also address the issues unique to multiple-target search; a much more complicated and error prone task. Given our previous work, we used both professionals and non-professionals to assess consistency.

Method

Professional (77 Transportation Security Administration (TSA) Officers) and non-professional (78 members of the Duke community) searchers engaged in a visual search task. Each trial could contain zero, one, or two targets in an array of 25 items total (Figure 1B). Targets were "Ts" and distractors were "pseudo-Ls" constructed from two perpendicular bars. The items varied in lightness, making some easy to spot and some hard to spot. Participants identified targets by making mouse-clicks on the relevant location(s). Consistency (standard error of response time/average response time) represented the variance in completion for correctly terminating search on single target trials.

Results

Participants revealed significant SOS errors; they were less accurate at finding a hard to spot target after finding an easy to spot target compared to when the hard to spot target was the only item in the display [Professionals: 45.86% vs. 58.95%, $t(75)=7.73$, $p<.001$; Non-professionals: 45.91% vs. 53.43%, $t(77)=4.77$, $p<.001$]. Interestingly, the professionals showed higher levels of SOS [$t(152)=2.29$, $p=.024$], although this was driven by them being more accurate on the single-target trials.

These results replicate the negative impact of multiple-target search; but, the primary question here is whether search consistency can overcome such detriments. Using regression models, we examined how much the variance in multiple target accuracy can be explained by two factors: response time and consistency in search behaviors (Figure 1C). For non-professionals, response time was the primary predictor of performance with consistency accounting only for a small portion of the variance. In contrast, search consistency was the primary predictor of performance for professionals with response time not accounting for any variance. In both regression models, more consistent visual search predicted increased accuracy for multiple target searches.

Importantly, there was also a significant correlation between SOS errors and search consistency ($r=.35$, $p<.05$), indicating fewer SOS errors in more consistent visual search. Although professionals and non-professionals may exhibit SOS errors in this task, we have identified at least one of the mechanisms contributing to the performance detriment.

Conclusions

Real world visual searches present a number of unique pressures, such as the potential for multiple targets to be found in any given display. Because we cannot always change these external factors to produce good visual search situations, it is important to identify characteristics of good visual searchers. Here we demonstrated that increased search consistency, or conducting a similar search from trial to trial, increased accuracy in multiple target searches and correlated with fewer SOS errors.

One potential reason for this enhancement in multiple target search accuracy is that consistency may reduce cognitive burdens—in performing a search, observers have to remember

what they found and where they found it (Cain & Mitroff, under review), but consistent visual search can make it easier to remember where search already has (or has not) been conducted following a found target. This link between accuracy and consistency is exciting given that the relationship is so strong and that this is a trainable skill for improving accuracy.

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